implantation into non-implantation regions other than implantation regions, a step for covering the non-implantation regions with the photoresists **112**, **113** becomes necessary. In addition, for promotion of efficiency of manufacturing steps, the p region **105** and the n region **106** configuring the diode for detecting temperature are often formed in the same step as the formation of the main element in the active region of the semiconductor substrate **101** by ion implanting (refer to FIGS. **9**C and **9**D), as described in paragraphs [0022] to [0023] of PTL 1.

However, the conventional diode for detecting temperature has large variation of the forward voltage Vf.

CITATION LIST

Patent Literature

PTL 1: JP 2002-190575 A (FIG. 1, paragraph 0016)

PTL 2: JP 03-34360 A (FIG. 1, First Embodiment)

PTL 3: JP 2007-294670 A (FIG. 6, paragraph 0019)

PTL 4: JP 2010-287786 A (FIG. 3, FIG. 4, paragraphs 0046-0050)

SUMMARY OF INVENTION

Technical Problem

The present invention has been made in view of the above-described points. It is an object of the present invention to provide a manufacturing method of a semiconductor device capable of reducing variation of a forward voltage Vf of a diode for detecting temperature, which is integrated on the same semiconductor chip in a semiconductor substrate.

Solution to Problem

In order to achieve this object, according to one embodiment of the present invention, there is provided a manufacturing method of a semiconductor device including: depositing a thin film semiconductor layer on a semiconductor substrate with an insulating film therebetween, the insulating film having been formed on a surface of the semiconductor substrate; ion-implanting first impurity ions into the thin film semiconductor layer under a condition where a range of the first impurity ions becomes smaller than a film thickness of the thin film semiconductor layer when being deposited; and selectively ion-implanting second impurity ions into the thin film semiconductor layer with a dose quantity more than a dose quantity of the first impurity ions, wherein a diode for detecting temperature is formed by a region into which the first impurity ions have been implanted and a region into which the second impurity ions have been implanted in the thin film semiconductor layer.

Advantageous Effects of Invention

According to one embodiment of the present invention, a manufacturing method of a semiconductor device capable of reducing variation of a forward voltage Vf of a diode for detecting temperature, which is manufactured by ion implantation into a polysilicon layer formed on the surface of an inactive region of a main semiconductor element with an insulating film therebetween, can be provided.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a main part cross-sectional diagram of a semiconductor device according to an embodiment of the present invention;

FIG. **2** is a relationship diagram between a film thickness of a polycrystalline silicon layer and a forward voltage Vf when the forward voltage Vf of a diode for detecting temperature according to the embodiment of the present invention has a film thickness dependency of the polycrystalline silicon layer;

FIG. **3** is a main part cross-sectional diagram for illustrating a manufacturing process flow of the semiconductor device according to the embodiment of the present invention;

FIG. **4** is a main part cross-sectional diagram for illustrating the manufacturing process flow of the semiconductor device according to the embodiment of the present invention;

FIG. **5** is a main part cross-sectional diagram for illustrating the manufacturing process flow of the semiconductor device according to the embodiment of the present invention;

FIG. **6** is a main part cross-sectional diagram for illustrating the manufacturing process flow of the semiconductor device according to the embodiment of the present invention;

FIG. **7** is a main part cross-sectional diagram for illustrating the manufacturing process flow of the semiconductor device according to the embodiment of the present invention;

FIG. **8** is a main part cross-sectional diagram for illustrating the manufacturing process flow of a semiconductor device according to the embodiment of the present invention;

FIGS. **9**A through **9**E are main part cross-sectional diagrams for illustrating the conventional manufacturing process flow of the semiconductor device;

FIG. **10** is a relationship diagram between a film thickness of a polycrystalline silicon layer and a forward voltage Vf when the forward voltage Vf of a conventional temperature sensing diode has a film thickness dependency of the polycrystalline silicon layer; and

FIG. **11** is a relationship diagram illustrating a relationship between a junction temperature of a diode and a forward voltage.

DESCRIPTION OF EMBODIMENTS

A relationship between the forward voltage Vf of a diode for detecting temperature, which is formed by a conventional manufacturing method, the variation (standard deviation) σ thereof, and the film thickness of a polycrystalline silicon layer as a starting material, which the present inventors found, is illustrated in FIG. **10**. As illustrated in FIG. **10**, it was found that the forward voltage Vf of the diode made of a doped polysilicon layer formed by ion implantation in a non-doped polycrystalline silicon layer having a film thickness of about 500 nm has a film thickness dependency in which the forward voltage Vf is decreased as the film thickness is increased when the film thickness of the polycrystalline silicon layer as a starting material changes by about ±30 nm. In addition, it was found that the variation (standard deviation) σ of the forward voltage Vf is large, 1.5 mV or more, and becomes larger in proportion to the forward voltage Vf. Here, in the case where the polycrystalline silicon layer is deposited to have a film thickness of 500 nm, in fact, a film thickness error of about ±30 nm cannot be avoided. Therefore, manufacturing of a diode by ion implantation into a polycrystalline silicon layer as a starting material with high energy of 100 keV or more results in an unstable cause associated with the forward